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KEEN'S REPORT NO. 2.

STUDIES

IN THE

SEASONAL HISTORY

OF

DENDROCTONUS BREVICOMIS

LAMB'S MINE UNIT ASHLAND

OREGON

Feb. 1917

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REPORT #2

SEASONAL HISTORY

OF

DENDROCTONUS BREVICOMIS

ASHLAND AREA

LAMB'S MINE UNIT.

PROJECT 15a.

By

F. P. Keen.

Scientific Assistant.

2. SEASONAL HISTORY OF DENDROCTONUS BREVICOMIS.

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REPORT # 2.

SEASONAL HISTORY OF DENDROCTONUS BREVICOMIS.

THE ADULT.

Food Habits:-

The host tree of Dendroctonus brevicomis is almost exclusively the Western Yellow Pine, Pinus ponderosa. It has been found by the writer attacking and killing large numbers of Pinus coulteri near San Diego, Cal; and in rare cases has been found in Sugar pine.

Experiment Cage D. (Hopk.U.S.No.14264)

On June 5,1916.- Three logs from a freshly cut Sugar Pine were placed in this cage, containing large numbers of D.brevicomis emerging from Yellow Pine bark.

July 25-1916- About 12 attacks of D.brevicomis were noted on one of the larger logs. Nearly ⅔ of the adults were dead in the galleries, having died before completing 1 inch of gallery. Two attacks had been more successful from 1/2 to 5 inches of gallery had been constructed, the parent adults were alive, eggs were noted and young larvae found in larval galleries 1/2 inch long. None of these came to maturity.

It was not definately determined whether the adults feed while constructing their gallery, although they very probably do. The major portion of the frass in the galleries is made up of small pieces of wood, cut out of the gallery with the mandibles and placed to one side.

Duration of Life.

With Normal Food.

Due to the difficulty of following a single beetle thru its developement, it was not possible to determine this point except indirectly.

Cage #2A. (Hopk.U.S.No.14243)

Oct.15,1915.-Tree attacked.

May.19,1916.-Last emerging.

Total -216 days.

Adding to this 15 days from beetle first formed to emerging and 15 days from emerging to attacking, gives 246 days duration of life for a beetle.

Tree 51-
Sept.12,1915- Tree attacked.
May 10,1916. - Last live parent adult noted.
Total of 240 days for life of adults in tree.

Other examples as in the following table:-

Table I

Tree No.	Date Attacked.	Last live Parent Adult.	Period Days.	First adult to attack	Duration of Life.
2A	Oct.15,1915.	May 19,1916.	216	30	246 days
51	Sept 12, " .	May 10, " .	240	"	270
56	Sept. 25," .	Apr.29, " .	217	"	247
67	Sept. 25," .	Apr.6 , " .	194	"	220
52	Sept.15, " .	May 10, " .	238	"	268
119	Sept.10,1" .	Apr.15, " .	218	"	248
92	Sept.20. " .	Apr. 6, " .	199	"	229
75	Oct. 5, " .	Apr. 29, " .	207	"	237
72	Oct. 5, " .	Apr.22, " .	200	"	230
73	Oct.5 " .	Apr.29. " .	207	"	237
63	Oct.10 , " .	Apr. 6," .	179	"	209
70	Oct.10, " .	May 27, " .	230	"	260
508	Oct. 20, " .	May 27, " .	230	"	250
62	Oct 14 , " .	May 27, " .	225	"	256
Average			214	30	244

This table shows an average life of the parent adults overwintering in the trees to be 214 days or about 244 days total. The maximum figure is a total of 270 days.

Without normal food.

Parent adults taken from Cage E on Sept 30 ,1916 and kept in a glass tube with a cotton stopper all died before Oct. 15 th.

New adults from tree #69 kept under similiar conditions also died within 15 days. It is evident that the beetles need moisture and food in order to live for any length of time. This would indicate that flight was not of great duration.

DURATION PERIOD.

The duration period, i.e. that period from first adults to last adults transforming, in any tree, averages 41.8 days for the overwintering generation and 18.5 days for the 1st seasonal generation.

Event Period.

The adult event period or the time between the maturing of a beetle and its emergence averages 18.2 days for the overwintering generation and 7.1 days for the 1st generation.

- Diagram #1 shows how the duration and event periods for adults, vary thruout the year. Thus these periods are prolonged in the spring and accelerated in the fall.

Proportion of sexes.

14260-Tree 311

From two slabs of bark, representing 4.35 sq. ft., 243 beetles emerged during Sept 1916, Of these 142 were female and 101 males. 58.5 % female and 41.5% male.

14260-Cage B-Tree 354.

From 37.6 sq. ft. of bark caged, during sept. 1916 185 parent adults emerged; of these 100 were females and 85 males, or 54% females and 46% males.

This excess of females is further explained by the fact that often polygamy is found to occur.

Tree 354.

This tree cut Sept. 15, 1916 was newly attacked by D. brevcomis. 20 sq. ft. of bark was carefully examined. Out of 66 attacks noted; 11 attacks were found containing 3 beetles each, of which 2 were females and one was a male. This shows the same percentage as emerged from this tree, namely 54% females and 46% males.

In these polygamus galleries, sometimes the two females were found in the lead, one at the extreme end doing the construction work, the second female about 1 inch behind, and the male two or more inches in the rear of the last female. In other cases the male was found in the middle of the gallery with one female in the lead and one behind him nearer the entrance.

Cage B. (14564).

Of the first 6 beetles emerging from this bark on Mar. 26., 4 were females and 2 males. This would indicate that both sexs start emerging at the same time.

Fertilization.

Age at beginning.

In some cases fertilization and egg laying occur very soon after emergance.

Cage C.

Aug. 3, 1916, Beetles, which had freshly emerged from bark, in Cage B, placed on log.
Aug. 9,- these had constructed 4" of gallery and laid several eggs.
July ~~30~~-7- ~~They probly~~ Later probably emerged from bark Cage B, placed on log.
July 10- Galleries 2½ long to put starting; few eggs.
July 29- Freshly emerged beetles liberated on log in cage C.
Aug. 3- Beetle had formed galleries from 1 to 3" long and laid eggs.

These records indicate that the beetles are capable of attacking and laying eggs within 3 days after emergence.

Mating Habits.

In spite of the almost continous observations which were carried on during the season, copulation was not observed. However, all the evidence points to the supposition that copulation occurs in the brood chamber soon after attack, instead of in flight as formerly supposed. This evidence is as follows:-

In cage B- were great quantities of bark was placed and which emerged over 4000 beetles, one date 1100 beetles being on the walls of the cage, not a single case of copulation was observed. Yet when these beetle were placed on a Yellow pine log in cage C- they ~~indicate~~ immediately commenced constructing galleries, the female commencing the operation and being seen followed by a male, and within 3 days eggs were laid.

It is qiute certain that copulation did not occur in cage B and as there was no flight period it is evident that copulation must have occured in the newly constructed gallery.

Cage D-

Fertility Experinent. Aug. 24, liberated 30 female D. brevicomis taken from cage C, (newly emerged adults) and placed on a freshly cut log. On Sept. 2, only 1 fenale had constructed a gallery which was 3 inches long and was Y shaped. No eggs present, The female was still alive and was apparently discouraged.

Sept 14 took 6 females (from trees 1060 and 359) fron short galleries with ne eggs or males present and placed on a log in cage D.

Sept. 22, 1 female had formed a gallery 3" long and had laid several eggs. But another one had formed a gallery 1" long with several brood-chambers but had laid no eggs. The gallery with the eggs was straight and without brood chambers. Apparently the female had been fertilized previously.

These expiriments show in the first place that females freshly emerged, or flying will not be able to lay eggs after attacking unless the male is allowed to enter the gallery. And again if the female is removed after attacking a tree, and before the male has found her and placed on a caged log, she

will not be able to lay eggs. The female which did lay eggs in this expiriment probably had been fertilized by a male in the gallery, and then been deserted.

Although the evidence so far is not conclusive, it all points towards the theory that copulation occurs in the brood chambers soon after the female has reached the cambium with the new gallery.

In recent conversation with Mr. Palph Hopping of the U. S. Forest Service; he informs me that upon two occassions he has actually observed copulation occuring within the galleries. This evidence would then verify the conclusions which I had already reached thru these experiments.

Attack.

Method of Attack:-

There appears to be no sudden or concentered attack on the part of the beetles, but rather a slow continuous attack, depending upon the abundance of attacking beetles; striking the tree at some weak point near the top and then gradually extending the attack down the trunk until the resistance of the tree is completely overcome. In the early spring this duration of attack is longer than later on when the attacking beetles are in abundance. In the early spring, the base of partly infected trees are selected and later on as the emergence of the beetles increases new and healthy trees are attacked.

In this connection a great number of trees were watched, while being attacked. The attack almost invaribly commencing on the top of the tree and working down until the entire tree was infected, the attack was continuous; extending over a couple of months in some cases.

Tree 661.

Apr. 25, First noted fading at the top, was probably being attacked at the top.
May 10. Pitch tube, could be seen above 20' from the ground.
June 3. Pitch tube, above, 15' from the ground, 1 female examing lower part of tree to find a place to attack.
June 10. Abundant attack to within 6' of the ground, below this a few attacks, 2 female just reaching cambium, males not present.

July 3- Last attack at base. Tree completely infected.

Tree 98.

Mar. 11- Fading at top probably attacked at top.
May 4 Abundant first attack at base of tree.

This is typical of a great number of trees, in fact all trees which fade first at the top and then gradually fade down to the base. During the height of the attacking perion, some trees are attacked so rapidly that it is as though they were attacked simultaneously thruout their length.

Noise of Attack.

The noise made by the beetles in making their attack has not been mentioned before. On warm days, at the height of the attacking period, when a tree is being abundantly attacked, The noise made by the beetles in chewing the wood in the construction of the galleries is very noticeable. They produce a faint crackling sound like the crushing of dried leaves, a noise very similar, only more continous and not as loud as that made by Cerambycid larvae in gnawing the wood.

In several instances, attention has been directed to infested trees which showed no outward sign of insect infestation, by fading foliage, pitch tubes or boring dust, thru the noise made by the attacking beetles. Trees 83, 98, 99, and others were located in this way.

Event period of attack.

The event period of attack, or the time from attack to first eggs, varies greatly with individual trees and with the generation and time of year, ranging from 4 days during the summer, the attack being on fallen logs, to 44 days in the early spring, when the beetles are attempting to attack healthy trees.

It averages 88 days in the attack of the attack of the overwintering g generation and 15 days for the first seasonal generation.

Duration Period.

The duration of attack, or first to last attack, also varies with the

time of year and the resistance of the trees. Averaging 13 days for windfalls, 44.6 days for the attack of the first seasonal generation and 29.7 days for the attack of the second generation.

TABLE II

SEX MAKING ATTACK.

Tree No.	No. Attack	Female starting burrow male not present.	Female at head of gallery male behind.	Female, male both just barely into cambium	Male ahead in gallery	Female with gallery eggs, male not present	2	2Females,1male in one gallery.	2Females,2males in one gallery.	2Males,1female in one gallery.
46'	3	2	1	1						
79	3	1	2							
99	4	1	3							
117	6	1	3		1	1				
140	1		1							
661	2	2								
1025	7	3	4							
1026	11	1	6		2*		1	1		
206	2		2							
211	1	2	1							
78	1		1				1			
203	2		2				3	2		3
354	55	2	45							
	101	15	70	1	3	1	5	3		3

* Female not found.

Construction of Gallery.

From many records it has been determined that the attack is made by the fe female. (See table II).

Tree 211.

June 2. Noted a female alight on a log, after 5 minutes of walking around and examining it she started boring into a crevice, within 6" of where she lit.

She finds a suitable spot in a crevice of the bark and bores almost d directly into the cambium. Here a small brood chamber is formed consisting of nothing more than an enlargement of the gallery to a decidedly wall

formed chamber with an L shaped entrance. At about the time she reaches the cambium she is joined by the male, who assists by pushing the excavated frass out of the exit hole. The female continues the gallery and is followed by the male, who has never been observed doing any of the actual excavating work.

From records on logs in cage C. and tree 211 it has been found that the female is able to construct on an average of .65 inches of gallery per day; and lay 188 eggs per day. They also build on an average of ..26 vent holes per inch or 1 vent hole every 4 inches.

Length of Gallery.

The maximum length of a gallery which any pair of beetles would form was not determined, but it was found from averages that they formed, at least 17. inches of gallery per attack.

Attacks per square foot.

The attacks made per sq. ft of bark ranged from 2.5 to 11 and averaged 4.8.

Oviposition.

Age at beginning.

As mentioned under fertilization, the records show that the beetles are capable of laying eggs 3 days after emergence. And assuming the average of 15 days for the beetles to emerge after maturing, would indicate that they were capable of laying eggs 18 days after maturing as beetles. This of course is the minimum time required, the average maximum time probably being very much longer.

Act of Oviposition.

The act of oviposition was not observed although a number of females were watched while constructing their galleries.

Position and number of egg niches.

The egg niches are located in the soft bark just off the main egg gallery, and separated from it by a wad of frass which is packed into the niches after the egg is deposited. Often when the bark is stripped from the wood,

the eggs are visible in their niches, but more often they are concealed by the frass packing, or a very thin layer of the phloem.

The number and distance apart of the egg niches varies very greatly with different attacks and even in the same galleries; being very irregular. Sometimes the eggs are only 1/16 inch apart and at other times there will be three or four inches of gallery with no eggs on either side. On an average there are 2.62 eggs per inch ofgallery.

Period of Oviposition.

The period of oviposition has not been very definitely determined. Commensing with the first eggs which are usually laid about eight days after attack, egg laying continues for from 10 to 49 days with an average of about 23 days.

This egg laying period, of course, is extended in the case of females which overwinter before depositing their full compliment of eggs. However, there appears to be a rather lengthy period, in some cases, after egg laying has ceased and before the adults die, that the adul parent adults remain in the trees without depositing eggs. Many live parent adults overwinter, and still do not lay any more eggs in the spring. It has not been definitely determined to what extent parent adults may leave one tree and attack and overwinter in a second or third one.

Eggs per Female.

The maximum number of eggs laid by any one female was determined as 41 with an average of 30. This figure is undoubtedly two low, as it was difficult to get the complete egg laying capacity of a female without disturbing or injuring her in some way.

The Egg.

Event Period.

The event period or duration of the egg stage was hard to determine except thru general averages of the time from first eggs laid to first larvae hatching.

TABLE III

EVENT PERIOD OF EGGS.

Tree No.	Generation	Eggs laid	Larvae Hatched	Event Period			Over-wintering
				Mim.	Av.	Max.	
39	1915-1	July 12, 1915	July 20, 1915	8	8		
24	"	" " "	" 24 "	12	12		
Average				8	10	12	
51	1915-2	Oct. 5, 1915	Oct. 20, 1915		15		
52	"	Sept. 27, "	Oct. 11, "		14		
63	"	Nov. 7, "	Nov. 27, "		20		
66	"	Nov. 27, "	Mar. 7 , "				100
2A	"	Nov. 3, "	Mar 7, "				124
"	"	Mar. 7, "	Apr. 8, "		32		
6262	"	Oct. 17, "	Feb. 12, "				118
Average				14	20	32	114
201	1916-1	May 20, 1916	June 12, 1916		23		
202	"	" " "	" "		23		
203	"	" 17, "	" 12, "		25		
"	"	" 29, "	" 23, "		20		
205	"	June 20, "	July, 10, "		25		
206	"	May 17, "	June 12, "		25		
211	"	June 9, "	July 4, "		26		
83	"	Apr. 22, "	May 27, "		35		
1026	"	" 30, "	June 7 "		38		
78	"	May 10, "	June 19 "		40		
117	"	" 1, "	May 27 "		26		
79	"	Apr. 22, "	May 27 "		35		
661	"	June 10 "	June 24 "		14		
Average				14-27.4-40			

The records show a average of 23.9 days for the hatching of the eggs, with a mimium of 8 days and a maximum of 40 days. Individual eggs may incubate in less time than this, but as records were not kept on individual eggs, the present event period indicates the length of egg period which is of importance in the development of the broods in the infested trees.

Duration Period.

The duration of the egg laying process like the duration of the attack is extremely variable and it is doubtful if the records are of much value since they do not represent the duration of the egg laying of a single beetle but rather the duration of the egg laying over the entire tree, or the part of the

tree examined.

TABLE IV

DURATION PERIOD OF EGG STAGE.

Tree No.	Generation	First egg laid	Last egg laid	Duration period Min.	Av.	Max.	Over-Wintering
99	1915-1	July 15, 1915	July 25, 1915		10		
24	"	" 9, "	" "		16		
Average				10	13	16	
54	1915-2	Aug. 20, 1915	Sept. 5, 1915		16		
51	"	Sept. 13, "	Oct 15, "		32		
50	"	" . 15 "	" 15, "		28		
52	"	" . 37 "	" 28		31		
63	"	Nov. 6 "	Feb. 6, 1916				92
66	"	Oct. 25, "	Nov.28, 1915		34		
2A	"	Oct 23, "	Nov. 26, "		34		
62	"	" 17, "	" . 13, "		27		
Average				16	29	34	92
83	1916-1	Apr. 22, 1916	June 5, 1916		42		
1026	"	" . 30, "	" "		34		
78	"	May 10 , "	" 24, "		45		
117	"	Apr. 22, "	" 10, "		49		
79	"	" . 20, "	" 3, "		44		
98	"	May 25, "	" 24, "		30		
661	"	June 17, "	July 7, "		20		
Average				20	37.7-49		

These records show that egg laying continues for about 30.8 days ranging from 10 to 49 days.

Number of Eggs per square foot.

The number of eggs per sq. ft. was not determined directly, but the number of eggs in sample lengths of gallery were counted and the number of inches of gallery per sq. ft. which, gave us an average of 636 eggs to the sq. ft.

Percent of Eggs hatching.

No definite figures were obtained on the average percent of eggs hatching. However, it was noted that in some cases a good many eggs die or are killed in

the egg niches. In some sour sap trees the entire brood may be killed by the moist condition. In other trees which are normal, a varying per cent fail to hatch.

Tree 203.

Examined May 29, 1916.			% of failure
1 egg gallery	27 egg niches	9 empty	33.3%
1 egg gallery	31 " "	6 dead eggs	19.3%
1 " "	40 " "	5 empty	12.5%
Total	98	20 Average %	20.4%

These records would indicate that from 12% to 33% or an average of 20% of the eggs fail to hatch.

Per cent of Eggs maturing.

The per cent of eggs which produce full grown emerging beetles is apparently very low, only about 12.6% of the eggs reaching the beetle state; or 1 egg in 8. This is indicated by the averages where 636 eggs are found to the sq. ft. and only 80 beetles emerge.

In some cases this death rate is even greater.

Tree 75- Slab 14428:-

From which 20 beetles emerged had 324 inches of egg gallery.
324 with the average of 3.39 eggs per inch 1098 eggs.
Or a death rate of 98.2%, or only 1.8% of the beetles maturing.

THE LARVA.

Food Habits.

The larva upon hatching commences boring its gallery at right angles to the egg gallery. The first 1/8 of an inch is usually under a small layer of the bark, then it goes deeper so that the bark is cut and the cambium reached, and sometimes the sapwood is faintly seared. After about a half inch, or more of gallery, it returns to the bark, or inner bark and commences working outward towards the outer bark. After about 7 days it reaches the junction of the inner and outer bark; where most of its development occurs. After it has nearly completed its growth it bores farther out, into the bark and forms an enlargement of its gallery in which to pupate.

Growth.

Molts:-

It was not determined how many times the larva molts, except that it sheds its skin upon changing to the pupa form. The pupa again sheding its skin on transforming to the adult.

TABLE V

EVENT PERIOD OF LARVAE.

Tree No.	Gener-ation.	Larvae Hatched	Larvae Pupated	Event Period Mim.	Event Period Av.	Event Period Max.	Over-Winter Mim. Av. Max.
24	1915-2	July 13, 1915	July 23, 1915		10		
35	"	" 15, "	Aug. 8, "		24		
Average				10	17	24	
34	1915-2	Sept. 4, 1915	Sept. 23, 1915		21		
			Apr. 6, 1916				214
53	"	" 8, "	Mar. 8, "				181
51	"	" 29, "	" 8, "				160
50	"	" "	" 21, "				173
52	"	Oct. 11, "	" 8, "				148
		Oct. 20, "	" 29, "				160
		Nov. 3, "	Apr. 16, "				164
119	"	Mar. 31, 1916	" 20, "		20		
75	"	Apr. 30, "	June 11, "		42		
63	"	Nov. 28, "	Mar. 30, "				122
		Oct. 4, 1915	Apr. 7, "				124
		Feb. 12, 1916	May. 11, "		88		
59	"	" 14, "	" 20, "		95		
66	"	Nov. 6, 1915	Mar. 21, "				135
		Nov. 21, "	" 31, "				130
		Feb. 13, 1916	May 11, "		87		
70	"	Mar. 8, "	" 7, "		60		
508	"	May 30, "	July 17, "		48		
2A	"	Mar 8, "	May 11, "		64		
		Apr 9, "	" 20, "		41		
		" 23, "	June 18, "		56		
62	"	Feb. 13, "	May 10, "		86		
		Mar. 8, "	" 18, "		71		
306	"	Apr. 6, "	" 30, "		54		
		" 16, "	June 19, "		64		
Average				20	60	95	122-155-214
83	1916-1	May 27, 1916	July 3, 1916		37		
	"	June 3, "	July 8, "		35		
		June 17, "	July 15, "		28		
1026		June 7, "	July 7, "	~~30~~	30		

Table V Concluded:-

Tree No.	Generation.	Larvae Hatched	Larvae Pupated	Event Period Mim.	Av.	Max.	Over-Wintering
	1916-1	June 19, 1916.	July 15, 1916.		26		
	"	June 29, "	July 20, "		21		
117	"	May 27, "	July 8, "		42		
	"	June 10, "	July 15, "		35		
	"	July 8, "	July 31, "		23		
79	"	May 27, "	July 9, "		43		
661	"	June 24, "	July 27, "		35		
	"	July 24, "	Aug. 5, "		32		
	"	July 22, "	Aug. 13, "	22?	22		
1069	"	July 9, "	Aug. 5, "		27		
	"	July 19, "	Aug. 19, "		31		
	"	Aug. 20, "	Sept. 5, "		16		
Average				16	30.2	43	

These records show the larval development period to be about 30 days for the 1st. generation and 60 days for the second generation. And 155 days over-wintering.

TABLE VI

Duration PERIOD OF LARVAE.

Tree No:	Gener-ation.:	First Larvae Hatched	Last Larvae Hatched	Duration Period. Mim.	Av.	Max.:	Over-Wintering.
39	1915-1	July 19, 1915.	Aug. 4, 1915.		16		
24	"	July 15, "	July 27, "		12		
35	"	July 15, "	Aug. 4, "		20		
Average				12	16	20	
34	1915-2	Sept. 4, 1915.	Sept. 17, 1915.		15		
51	"	Sept. 29, "	Oct. 25, "		24		
50	"	Sept. 25, "	Oct 25, "		30		
52	"	Oct. 11, "	Nov. 3, "		23		
63	"	Nov. 28, "	Feb. 12, 1916				76
66	"	Nov. 6, "	Feb. 13, "				99
2A	"	Mar. 8, 1916	Apr. 23, "		46		
62	"	Feb. 13, "	Apr. 6, "		52		
Average				15	31.7	52	87.5
83	1916-1	May 27, 1916	June 17, 1916		21		
1026	"	June 7, "	June 29, "		22		
17	"	May 27, "	July 8, "		42		
661	"	June 24, "	July 22, "		28		
1069	"	July 9, "	Aug. 20, "		42		
Average				21	31	42	

These records show the duration of larval hatching to be about 31 days for both the 1915-2 and 1916-1 generation. Where the hatching is discontinued on account of cold weather, this period is extended to about 88 days.

THE PUPA.

The pupal stage, or the stage in which the beetle undergoes the greatest physiological change, and is very sensitive to outside influences, such as heat and cold.

It has been definitely observed that a larger percentage of pupae are killed by the early frost. This probably accounts for the fact that pupae have never been observed overwintering.

This killing is greater when a period of warm weather is followed by sudden killing frosts. If a period of cold weather preceeds the frost, very few pupae form and hence very few are killed.

Pupal Event Period.

The period from the formation of pupae to the forming of adults is a very consistent event.

	Mim.	Average.	Max.
1914 -2nd generation	10	26.2	39
1915 -1st "	6	11.8	21
1915 -2nd "	8	26.2	40
1916 -1st "	7	10.7	16

Diagram 2 shows how the event period varied thruout the two years 1915 and 1916.

Pupal Duration Period.

The records show an average duration period of 18 days for the first seasonal generation with a minimum of 6 and a maximum of 38 days.

For the 2nd seasonal generation this duration period average 40.7 days, with a minimum of 13days and a maximum of 92 days.

[illegible]

EMERGENCE.

Emergence of Overwintering Broods.

Emergence of the overwintering new adult commences with the first warm weather in the spring. This may be as early as the 25th of February, and the emergence of these adults is practically complete, by the first of April and by the time the emergence of the spring brood of adults commences.

Which Sex Emerges First.

A few obserbations in Cage B, would indicate that both sexes commence to emerge at the same time.

Cage B.

May 26- First emergence, 6 adults of which 4 were females and 2 males.

Swarming or Continuous Emergence.

As is the case with attack, the emergence of the beetles from a tree extends over considerable time. Their emergence depending a good deal upon weather conditions. During the period of emergence a few hot days will cause the beetles to leave the trees in swarms while a week or so of cold weather, will almost completely stop emergence.

As shown from the table of duration peroid of emergence:-

1914-2nd generation		25.8	Average	15	days	min.	63	days max.
1915-1st	"	21.5	"	16	"	"	27	" "
1915-2nd	"	61	"	27	"	"	90	" "
1916-1st	"	46	"	20	"	"	72	" "
Average		38.5	Gross	16		Gross	90	

Event Period of Emergence.

The period, between the time of a beetles formation and its emergence, or the event period of emergence, averages 13.5 days with a minimum of ½ day (a doubtful record) and a maximum of 43 days.

TABLE VLL

DURATION OF EMERGING.

Tree No.	First Emerging.	Last Emerging	Duration Period Min.	Av.	Max.	Over Wintering	Generation
34	Oct. 21, 1915.	Apr. 5, 1915				166	1915-2
34	May 28, 1916	July 16, "		49			"
97	Apr. 7, "	June 15, "		69			"
53	Oct. 20, 1915	Apr. 5, "				167	"
53	Apr. 30, 1916	July 17, "		78		"	"
51	Apr. 6, "	June 25, "		80			"
56	Apr. 6, "	June 4, "		59			"
50	Apr. 15, "	June 3, "		57			"
68	Apr. 15, "	June 18, "		64			"
67	Apr. 16, "	July 4, "		79			"
69	Apr. 17, "	July 4, "		78			"
86	Apr. 18, "	July 4, "		77			"
94	Apr. 30, "	July 9 , "		70			"
52	Apr. 23, "	June 4, "		42			"
54-	May 5, "	July 4, "		60			"
57	Apr. 23, "	July 3, "		72			"
64	Apr. 23, "	July 1, "		69			"
119	May 11, "	July 15, "		65			"
118	May 15, "	July 15, "		61			"
92	May 11, "	July 15, "		65			"
60	May 28, "	July 23, "		56			"
75	May 20, "	July 4, "		45			"
72	May 11, "	Aug. 3, "		84			"
73	May 11, "	Aug. 6, "		77			"
59	May 11, "	June 25, "		45			"
63	May 10, "	June 24, "		45			"
65	June 4, "	July 16, "		42			"
66	May 11, "	July 16, "		66			"
40	May 28, "	June 25, "		28			"
70	May 28, "	June 24, "		27			"
61	June 4, "	Sept. 2, "		90			"
508	June 3, "	Aug. 6, "		64			"
2A	June 4, "	Aug. 12, "		69			"
62	June 24, "	July 31, "		37			"
506	June 22, "	Augs 5, "		44-			"
Average			27	61	90-	166.5	
83	July 22, 1916	Aug. 11, 1916.		20			1916-1
1026	July 20, "	Sept. 30, "		72			"
117	July 29, "	Sept. 11, "		44			"
79	July 31, "	Sept. 9, "		40			"
98	Aug. 2, "	Oct. 11, "		70			"
661	Aug. 11, "	Sept/ 23, "		43			"
1069	Augs 26, "	Sept. 30, "		35			"
311	Sept. 2, "	Oct. 28, "		56			"
320	Sept. 23, "	Oct. 28, "		35			"
Average			20	46	72		

Y

Struggling Emergence.

The emergence from the trees is undoubtedly more prolonged than it is ordinarly supposed to be from a superficial examination of the trees. As the emergence from a tree decreases one is apt to examine many square feet of bark without finding any beetles, yet if this bark were placed in a cage, beetles would be found emerging for many more weeks.

This, first was shown by the bark which was placed in Cage B., for the flight experiment, which was taken from log 61.

Cage B.& Log. 61.

	First Emergence	Maximum Emergence	Last Emergence	
Cage B.	May 26, 1916.	July 7, 1916.	Sept. 2, 1916.	99 days
Log 61	June 3, "	July 7, "	Aug. 3, "	61 days

This shows 38 days longer duration period for the caged bark than for the bark on the tree. It also shows that maximum emergence occured just half way between first and last emergence.

This fact of straggling emergence helps to explain the long lapse of time between the emergence of the beetle, and their apparent attack.

½ Emergence of Overwintered Parent Adults.

In order to determine what becomes of the parent adults which overwinter a cage was built over log 2A on Mar. 9, 1916; this log containing parent adults and eggs, which had overwintered; and very small larvae which had just hatched.

TABLE VIII

OVERWINTERING PARENT ADULT EXPERIMENT.

Cage 2A-Hopk. U.S. No. 14248

Date 1916	Condition of Brood in Old Log						Holes in slab.	Beetles out in cage.	New Attack on old log.	New Attack on new log.	Condition of Brood in New Log						Remarks
	Pa	Pa	L	P	A	Em					Ad	Em	L	P	A	Em	
Mar. 9	m	fm	f														Tree caged.
Mar. 11	m	fm	f					6									D. Brev. flying outside
Mar. 15	m	fm	f					8	7								Ips.emarginatus inside
Mar. 17	m	fm	f														
Mar. 25	m	fm	f						4								A few Ips. outside.
Mar. 26	m	m	f					8									Stormy weather.
Mar. 31	m	l	m					18	3								
Apr. 1	l		m					3									
Apr. 4	l		m					21									
Apr. 8	l		l					110	1								
Apr. 12	l		f					20	2								
Apr. 15	l		f					14									
Apr. 22	l		f					6		2	f						
Apr. 26	l		p-l					70	1	2	f						
Apr. 29	l		p-l				157	25	1		f						
May 2	l		m					19	3	9	f						
May 10	l		m	f			30	8	1	2	f						Ips emarginatus flying
May 15	l		m	f			3	3			f						1 Hister ? Hyproph-loeus
May 18	l		m	m							f						
May 19	l		l	m				1		1	f	f					
May 27			l	m				3				f					New attack not successful
June 3			l	m	f			7				f					3 or4 Ips emargi-natus.attack
June 9			l	m	m	f	2	112		21	f	f					
June 17			l	l	m	m	178	110		16	f	m					
June 24					m	m	132	94		40	m	m	f				Many of the new attacks
July 3					m	m	100	122		18	m	l	f				are by Hylurgops Ips etc.
July 8					m	m	210	165		26	l	l	m				Not all D. Brev.
July 15					l	l	20	18		14	l	l	m				
July 22					l	l	5	15			l		m	f			
July 29					l	l	1	13					m	m			
Aug. 11					l	l		8					l	m	f		
Aug 19								4						m	m	f	Hot weather.
Aug. 26															l	m	Ips. emarginatus,
Sept.11															l	l	Hylurgops in new log.
Sept.23																	Hylurgops adults in new log.

Parent adults extending galleries.

Legend-: Pa-Parent adults. Eg.-Egg
: L-Larvae
: P-Pupae
A-Adult.
Em-Emerging
f-first event
m-maximum activity
l-last activity.

The records from this experiment show that the parent adults which overwinter in the trees, emerge during March, April and May. They will attack again, but their attack is mainly upon the uninfested portion of the infested trees, being unsuccessful on green timber.

The results of this experiment are more or less verified by observations in the field. Practically all of the first attack which was assumed to be by overwintered parent adults, since the new brood had not developed, was upon the base of prevously infested trees, and upon green strips of bark or partially infested trees. It was not until after the first emergence of the new brood of adults that attacks were noted on new and healthy trees.

Second Attack.

The development of the brood in the second log which was placed in cage 2A, would indicate that this brood developed from the attack of the new brood of adults, and not from the first attack of the overwintered parent adults; as their attack was unsuccessful.

Emergence of Parent Adults During Active Period.

To determine if the parent adults which, make their attack during the summer or fall, emerge from the trees after laying eggs, tree 354 was felled and a portion of it caged. This tree was attack early, by the 2nd generation of 1916.

TABLE IX

CAGE E TREE 354 HOPK. U. S. NO. 14260 PARENT ADULT EXPERIMENT

Date. 1916	Condition of Brood. A	E	L	P	A	E	No Parent Adults Emerging. Male	Female	Total	Remarks
Sept. 7	m	m								Tree caged.
Sept 14	l	l	f							
Sept 21		l	f				48	62	110	37.6 sq. ft.bark.
Sept 23		l	m				7	4	11	8.55 beetles to
Sept 30			m				25	27	52	sq. ft.
Oct. 4			l				1		1	
Oct. 7			l				1	3	4	
Oct 17							3	3	6	
Nov. 8								1 dead	1	
							85	100	185	57.5% Emerged.

From a count of 20 sq. ft. of bark on this tree it was determined that there were 8.55 parent adult beetles per sq.ft. This would indicate that 57.5% of the parent adults emerged. It also shows that this emergence occurs at about the time the brood had reached, ¼ grown larvae. (Maximum emergence of the overwintered parent adults, in Cage 2A, also occured at about the time the brood had reached ½ grown larvae).

This log is still caged and it will be determined next spring if the ~~overwinter~~ remainder of the parent adults emerge or die in the galleries.

FLIGHT.

Very little was determined in regard to the flight habits of the beetles. (The experiments under flight are given in a separate account).

The first beetles flying were observed Mar. 11, this acrresponds to the period of emergence of parent adults and emergence of overwintered new adults.

Maximum flight was recorded on May 1st. and 15 th these dates coinsiding with the period of maximum emergence. How long the beetles remain in flight before attacking was not determined. However it was found that they were capable of attacking 3 days after emergence, if placed upon a suitable log, as was done in Cage C.

From the plots showing quantity of emergence and quantity of attack on different dates, it would appear that maximum attack followed maximum emergence by 26 days.

OVERWINTERING.

Entrance into overwintering condition.

Activity of the beetles continues in all stages in the fall as long as warm weather lasts. As cold weather begins, activity gradually decreases until it practically stops altogether. The length of the active season influences to a large extent the proportion of the different stages which will overwinter.

Stages Overwintering.

In 1915, the season was long, cold weather beginning very late in November. It was therefore posible for the partial third generation to make their attack and reach the egg stage. While the earlier part of the second generation reached the pupae and adult stage. In 1916 the season being shorter, there was not the opportunity for the partial third generation to progress very far. This caused the greatest proportion of the overwintering brood to be made up of the larvae of the second generation and new adults which had formed, but which had not emerged to any great extent.

Pupae have never been found overwintering. Those which had reached that stage were killed by the first heavy frosts, and the broods continued then as larvae and new adults.

Thus we find overwintering:- New adults of the second generation; larvae from full grown to very small of the second generation; eggs and parent adults of the second generation; and parent adults and eggs of the third generation.

Number of Adults Overwintering.

The number of new adults overwintering is very small. Out of the 217 trees representing the overwintering brood of 1915; only 11 trees contained new adults, and even in these trees the proportion of the beetles was small.

Of the 3,379,500 beetles emerging from the 1915-2 generation only about 89,500 beetles overwintered as such, or 2.65% of the total.

Activity of Overwintered New Adults.

After the first of November, the new beetles that have formed, appear to prefer to remain in the trees rather than emerge even if a few warm days occur. However with the beginnig of warm weather in the spring, these beetles are the first to become active and emerge during the latter part of February and the first of March.

Length of Overwintering Period.

Averages of the hibernation periods, as shown in tables III, IV, V, VI and VII, indicate 146 days, of inactivity for any given stage.

In general as shown in diagram 5, there is aproximtely 80 days of inactivity between the last activity in the fall, and thebeginning of activity in the spring. In 1915-1916 this period was from Dec. 6th until March 1st.

LIFE CYCLE.

Development of Broods in Record Trees.

In the tabulation of the data on the record trees the following definitions have been used, following Dr. Hopkins scheme as presented in his "Seasonal History Studies."

Event period-Number of days between first attack to first egg, first egg to first larvae.

Duration period.- is the period between the first and last of any stages, as first egg to last egg laid, first larvae hatching to last larvae hatching.

Brood period- is the period between the first attack to the last emergence, or to any other stage.

From these definitions the following equations are true:-

First attack to first egg equals 1st event period.
" " " " larvae " Brood period to 1st larvae.
" " " " pupae " " " " " pupae.
" " " " adult " " " " " adult.
" " " " Emerting " " " " " emerging.

First attack to last larvae hatching equals brood period to larvae
" Plus duration period equals last egg seen
" " " "pupae forming " brood perion to pupae (larvae)
" Duration perion-(last ~~egg~~ larvae seen.)
" " " " adult " brood period to Adult. (~~pupae~~ Pupae)
" duration period-(last ~~egg~~ seen.)
" " " " emerging " brood period to emerging.
" duration perion-(last adult seen.)

" " " " last attack equals duration period of attack.
" " " " " egg seen " brood period to larvae. Plus
" larvae duration period.
" " " " " larvae seen" brood period to pupae. "
" pupae duration period, (emerging)
" " " " " adult seen " brood period to emerging duration period
" " " " " Emerging" " " " " " " "

Diagram 3 shows in a graphic manner the event and duration periods for the different broods thruout the year, as given in table X-i.

Diagram 4 shows the length of brood periods thruout the year.

GENERATIONS.

In diagram 5 we have summed up all of the knowlddge gained in two years work on theseasonal history of D. Brevicomis.

In this diagram the axis of the abscissa represents days thruout the two years, 1915 and 1916. Each interval equals 5 days. The ordinate of the diagram represents units of infestation" as used by the writer. (A unit representing 224 sq. ft of infested bark. It is in this case as accurate a measure of infestation as can be used since the area of infested bark was computed for each infested tree.)

Starting at the lower left hand corner, the first vertical column gives the number of units of infestation for each generation; the second column the actual number of infested trees.

Following the legend used thruout these reports for the different activities of the beetles we then have curves showing the commencing of each activity, the number of units in which the activity is occuring until the apex of the curve is reached which is the maximum event date and then the decline of the activity until the last event date is reached.

Thus is the case of the overwintering generation of 1914; we had 55 actual trees containing 60 units of infestation, (13,450 sq ft. of infested bark). Pupae commenced forming March 21st and increased until April 21st when it reached its maximum, with pupae forming in 33 units. Pupation then decreased until it ceased altogether on June 5.

First adults April 5 Maximum adults May 10 last adults June 24.
First emerging April 14 Maximum June 7 Last emerging July 19.

1915- 1915-1st Generation.

The 1st generation of 1915 was a small one of 27 actual trees and 30

units of infestation.

1st Attack June 25 Maximum July 13 Last attack July 22.
1st Emerging Aug. 5 Maximum Aug. 26 Last atta emerging Sept. 7.

1915-2nd. Generation

The 1915-2nd generation attack ~~was~~ undoubtedly largely came from the emerging beetles of the overwintering generation. As the diagram shows--.

1st Attack started Aug. 12th. There were two periods of attack reaching their maximums on Sept. 26th and Oct. 27th with last attack about Nov. 30 or on the approach of cold weather.

From the earlier attack some beetles ~~feun~~ formed and emerged about Oct. 30th, which gave them a chance to attack again before cold weather. This is the partial third generation which as shown in the memorandum of Dec. 4, 1915, not only occurs in the field but has been carried thru, under conditions of control in cages at the station.

This second generation is the large generation consisting of 217 actual trees and 200 units of infestation.

Although the attack in the fall was straggling, pupation in all trees occured at about the same time reaching a maximum on April 8th, 13 days earlier than the previous year.

Emergence of the overwintered new adults commenced about Feb. 28th and continued until April 3d when the main brood from overwintered larvae commenced emerging.

Emergence reached a maximum on May 29th and the last stragglers were out by Sept. 3d.

1916-1st Gemeration.

The attack of the first generation of 1916 commenced early in the season, about Mar. 4th beginning with the attack of the overwintered new adults. Attack reached a maximum on about June 22, when about 52 units were being attacked.

Maximum emergence of this generation occured on Aug. 22nd and the last adults were out by Nov.11th.

This generation consisted of 115 units in 118 actual trees. Although considerably greater than the 1915-1st generation, this generation again failed to reach the size of the previously overwintered generation. This would tend to prove that the 1st seasonal generation is only a partial one.

1916-2nd. Generation.

Attack on the trees of the second generation commenced on the 1st of August and reached its maximum on Sept. 6th. Up to the end of the year (1916) only 37 actual trees had been found, but probably only 1/6 have been found due to the failure of the trees to fade in the fall of the year of attack. Up to December 1915, only 37 of the 1915-2nd generation trees of which there were ultimately 217, had been found.

As in 1915, quite a few beetles of this generation completed their development and emerged. This again allows for a partial 3rd generation.

Number of Generations Annually:

From an examination of Table X-k it will be seen that the minimum brood period recorded is 54 days. This is undoubtedly too small ; but assuming that all broods could develop as rapidly thruout the year it would be possible to have 6 generations a year.

Again taking the maximum length of brood as 348 days it will be seen that the minimun number of generations possible, will be 1 generation a year. Taking the average length of brood period for the 1st and second generation, we would have an average number of generations a year.

From an examination of diagram 5, we see that in every year there are three periods of attack; and each beetle activity. Thus there are three periods of attack; three of egg laying; three of larvae hatching; three of pupation; three of beetle forming and three periods of emerging.

interupted by winter and begin again where they left off in the fall.

But in general, these generations group themselves into three periods of activity each year. These periods can be recognized in the field and make up what we commonly call the separate generation of the beetles.

Overlapping of Generations:

As has been shown in diagran 6, if we try and follow any particular family of beetles thru all of their generations we find that there is a hopeless confusion of overlapping generations. Thus the 3rd generation from the first emerging adults, may overlap with the 1st generation from the last emerging adults. If this is followed out permutations and combinations of overlapping are limitless. But if we do not try to follow any single group of beetles, but rely on the periods of activity as shown in diagran 5, the overlapping is very slight indeed.

Thus following the ~~prupx~~ pupation periods for the two years we find between the 1914-3nd generation and the 1915-1st generation, 36 days when no pupae are forming; between the 1915-1st generation and 1915 2nd generation, 36 days of inactivity; between the 1915-2nd generation and the 1916-1st generation in 1916, we find 8 days when no pupae are forming; between the 1916-1st generation and the 1916-2nd generation we have 11 days of overlapping in in which there is only a very slight activity.

The periods of attack and emergence overlap to a greater extent, but their periods of maximum activity are well defined and widely separated.

However, if we are speaking of the overlapping of any activity of one generation over some other acitivity of another generation we find that the period of emergence of one generation overlaps the period of attack of the following generation. In fact they almost coincide one with the other.

Thus the attack of the 1916-1st generation occurs during the same period as the emergence of the beetles from the 1915-2nd generation. And again the

attack of the 2nd generation of 1916 occurs during the period of emergence of the 1916-2nd generation.

BEETLE STATISTICS.

The following tables compile all the data which has been obtained so far on the various beetle activities, and possibilities of work, egg laying and so forth.

TABLE XL-a.

Beetles Emerging Per Square Foot

Tree No.	Square Feet of Bark	No. of Exit Holes	Beetles per Square Foot.
119	2	152	76
118	2	258	129
75	2	278	139
76	2	224	112
77	2	162	81
67	2	335	167.5
63	2	219	109.5
64	2	235	117.5
82	2	209	104.5
70	2	111	55.5
1051	2	295	147.5
2	3.43	234	68.4
508	2	146	73
54	3.5	410	117.1
27	3	181	60.3
61	2.44	108	44.3
56	1.26	186	147.2
69	1.71	184	107.5
64[illegible]	2.37	288	120.5
86	2.48	227	91.5
2A	2.64	361	136.8
57	2.08	129	62.1
65	1.58	43	27.2
662	1	108	108
72	2.14	135	63.1
65	1.29	78	60.5
2	5.45	395	72.5
508	2	194	97
54	2.04	35	17.2
27	3	198	66
61	.97	98	101
2A	5.12	644	25.7
79	1	23	23
83	1	33	33
98M	2.5	12	5
98[illegible]	2.72	358	131.5
98S	3.19	140	43.9
117	2	193	96.5
311	9.34	985	105.5

Table XI-a. concluded.

Tree No.	Square Feet of Bark	No. of Exit Holes	Beetles per Square Foot.
611	6.34	133	21
987	.5	145	290
1064	1	24	24
1026	2	127	63.5
1026N	2	79	39.5
1026T	4	57	14.3
1026S	6	195	32.5
Total	117.21	9365	80.

Min.-5 Max.-290

TABLE XI-b.

EMERGENCE TO RAW ATTACK.

Tree No.	No. of Attacks.	Emergence:	Emergence per Attack.
83	11	33	3
117	16	193	12.1
1026	15	127	8.5
987	21	18	.8
R	18	358	19.9
S	8	140	17.5
661	29	133	4.6
203	17	114	6.7
Average			95.

TABLE XI-c.

INCHES OF GALLERY PER SQ. FT.

Tree No.	No. Sq. Ft.	Inches Gallery	Inches per Sq. Ft.
125	1	160	160
554	20	1129	56.4
311	1	320	320
102	1	284	284
75	2.75	324	118
Average			197.8

TABLE XI-d.

EGGS PER FEMALE.

Tree No.	No. Females	No. Eggs	Eggs per Female
203	1	31	31
203	1	41	41
[illegible]	1	22	22
211	1	37	37
203	1	36	36
Average			32.7

TABLE XI-e.

EGGS PER FEMALE PER DAY.

Tree No.	Male: No. Days.	Female: No. Days.	Eggs per Female per Day.
211	9	4	2.29
211	28	11	2.54
Average	37	15	2.47

TABLE XI-f.

PARENT ADULTS PER Sq. FT.

Tree No.	No. Sq.Ft.	Parent Adults	Parent Adults per sq. ft.
554	20	171	8.55
Average			8.55

TABLE XI-g.

PARENT ADULTS PER ATTACK.

Tree No.	Attack	Parent Adults	Parent Adults per Attack
554	66	171	2.59
Average			2.59

TABLE XI-h.

INCHES GALLERY PER ATTACK.

Tree No.	Attack.	Inches Gallery	In. Gallery per Attack
554	66	1129	17.1
203	1	20.5	20.5
205	1	10.75	10.75
205	1	12.25	12.25
205	1	12	12
Average			14.5

TABLE XI-i.

EGGS PER ATTACK.

Tree No.	Attack	Eggs	Eggs per attack
203	1	35	35
211	1	37	37
203	1	31	31
203	1	41	41
205	1	40	40
554	66	2400	36
Average			33.4

TABLE XI-j.

INCHES OF GALLERY PER DAY.

Tree No.	No. Attacks	Inches per Day	Days	In Gallery per Day.
Cage C	1 1	4	6	.66
"	1 3	3	9	.33
"	1 3/4	3	4	.75
211	1 3/4	3	4	.752
211	1 3/4	3	3	1.00
211	1 1	8	11	.73
Average				.85

TABLE XI-k.

ATTACKS PER Sq. FT.

Tree No.	No. Attacks	No. Sq. Ft.	Attacks per Sq. Ft.
263	17	4.5	3.78
661	21	3	7
83	11	1	11
117	16	2	8
1046	10	1	10
1026	15	2	7.5
354	66	20	3.3
98	21	2.6	8.1
98	18	2.72	6.6
98	8	3.19	2.5
661	29	6.34	4.6
Average			23 6.8

TABLE XI-l.

VENT HOLES PER ATTACK.

Tree No.	Attack.	Vent Holes.	Vent Holes per Attack
2A	6	19	3.17
708	17	25	1.47
117	16	11	.69
208	1	7	7
263	1	1	1
238	1	7	7
354	66	264	4
661	29	33	1.14
83	11	1	.09
1026	15	11	.6
1040	5	12	2.4
1040	22	38	1.77
1040	10	10	.
Average			2.15

TABLE XI-m.

EGGS PER INCH OF GALLERY.

Tree No.	No. Attacks	Inches of Gallery	No. Eggs	Eggs per In. Gallery
203	1	12	35	2.92
211	1	3	9	3.00
211	1	8	28	3.5
125	1	8	46	5.75
125	1	6	43	7.17
125	1	6	31	5.16
203	1	12.25	27	2.21
203	1	10.75	31	2.89
203	1	20.5	40	1.95
354	1	114	243	2.13
102	12	10	58	5.8
		210.5	521	3.39

TABLE XI - n.

VENT HOLES PER INCH OF GALLERY.

Tree No.	No. Attacks.	Inches of Gallery:	Vent Holes	Vent Holes In. Gallery
203	1	12.25	7	.57
203	1	10.75	1	.09
203	1	20.5	7	.34
354	1	1129	264	.23
		1173.5	279	.27

TABLE XI-o.

NO. OF VENT HOLES PER SQ. FT.

Tree No.	No. Attacks	sq.ft.	Vent Holes.	Vent Holes per sq. ft.
117	2		11	5.5
354	20		264	13.2
661	6.34		33	5.2
95	1		1	1
1026	2		12	6
1040	1		12	12
1040	2		28	14
1040	1		10	10
1069	1		1	1
203	4.5		25	5.5
	40.84		397	9.0

TABLE XI-p

SUMMARY OF EXPERIMENTAL DATA.

		Per. Sq. Ft.	Per Attack	Per Female	Per Inch Gallery. Male	Per Day.
Attack	Min.	2.5				
	Av.	6.8				
	Max.	11				
Parent Adult	Min.					
	Av.	8.55	2.59			
	Max.					
Inches Gallery	Min.	56.4	10.7			.33
	Av.	187.8	18.5			.65
	Max.	320	20.5			1.00
Eggs.	Min	31	31	22	1.95	2.29
	Av.	36.4	36.4	32.7	3.39	2.47
	Max.	41	41	41	7.17	2.54
Vent Holes	Min.	1	.09		.09	
	Av.	9	2.61		.27	
	Max.	14	7		.57	
Emergence	Min.	5	.6			
	Av.	80	9.5			
	Max.	290	1919			

TABLE XII

ADJUSTED TABLE of BEETLE STATISTICS.

	Per Sq. Ft.	Per Unit Tree	Per Attack	Per Parent Adult	Per Female	Per Male	Per Inch of Gallery	Per Egg	Per Emergence	Per Day.
Attack	6.8	1523		.386	.69					
Parent Adults	17.6	3941	2.59							
Females 56%	9.85	2204	1.45			1.27				
Males 44%	7.75	1737	1.14		.786					
Inches Gallery	187.8	42,040	27.6	10.7	19.05					.65
Eggs	636	142,500	93.6	36.1	64.6		3.39		7.95	2.20
Vent Holes	17.7	3964	2.61	1.0	1.8		.09			
Emergence	80	17,920	11.8	4.55			.426	.126		

SEASONAL ABUNDANCE.

Possible Annual Progeny of One Female.

Taking the data in table XII with an average of 65 eggs per female, and with 2 generations a year we would have from one female: 1 female after 1st generation- 65 adults of which 56% of 36 are females. 36 females with 65 eggs per female, after 2nd generation equals 2340 adults of which 56% of 1310 are females.

Thus we have a possible increase of 1310 times in two generations. This of course is never reached in nature, but it shows what a trememdous possibility thereis of an epidemic occuring within a year, if all the natural conditions are favorable to the beetles development.

TABLE XIII

Possible Pregeny 1914-1916.

	Parent adults		Eggs per P. A.		Total possible progeny.
1914-2nd	236,000	times	36.1	equals	8,520,000 beetles.
1915-1st	121,700	"	36.1	"	4,390,000 "
					12,910,000 "
	Subtract for attack of 1st generation				121,700 "
					12,788,300 "
1915-2nd	12,788,200	Times	36.1	Equals	464,000,000 "

TABLE XIV.

Effective Progeny for 1914, 1915, 1916.

Gen.	Units Inf. Pa. per unit.	Attacking Parent Adult	Beetles emer. per unit.		% of Emergence Attacking.
1914-2	59.89 times	3941 equals 236,000 times	17,920 equals	1,072,000	
1915-1	30.82 " " "	121,700 "	" "	553,000	11.3%
1915-2	199.10 " " "	785,000 "	" "	238,000* / 3,332,000	52.2%
1916-1	115.26 " " "	454,500 "	" "	2,068,000	12.7%

*First years emergence.

Comparing table 14 with table 13 we see that the emergence from the 1914 trees was o 12.8% of the possible emergence had all the eggs matured. And the emergence from the 1915-2nd generation trees was only .77% of the possible progeny if all the beetles of 1914 had made attack and all their eggs developed.

From table 14 it is evident that only about 12% of the beetles emerging from the overwintering brood made the attack of the 1st generation in 1915-1916.

And again, that from the available progeny of the 1914-2nd and the 1915-1st generations only 52.2% were effective in making the attack on the 1915-2nd generation trees.

Abundance During the Year.

Diagram 7 shows the number of beetles emerging every 3 days thruout 1915 and 1916, with the number of beetles attacking. Diagram 8 gives the totals for emergence and attack during these two years for each generation. The attack of the 1916-2nd generation is not shown as the total infestation is not yet known.

NATURAL CONTROL.

Climate Control.

A few cases of the effect of climate upon the development of the beetles have been noted.

Effect of Cold.

Without doubt sudden frosts during the active periods of beetle development serve to kill large numbers especially pupae.

Tree 54:

Oct. 20, 1915:- Quite a large portion of the brood have reached the pupal stage and at least 50% of the pupae are dead in the cells. An exceptionally heavy frost last night was undoubtedly the cause.

Tree 54:

May 10, 1916:- Heavy frost last night; many pupae and prepupal larvae sick, apparently frozen.

Tree 2A-(Log):

May 10, 1916:- Nearly all of the pupae and prepupal larvae look sick and yellow. Probably killed by the late frosts. Some larvae have turned black.
May 19, 1916:- Most of the larvae and pupae were killed by a frost about May 10. All on the top and on exposed oprtions of the log were killed. Some survived on the under side and where sheltered by leaves. Those inside of the cage, covering a part of this log were not injured.

These notes indicate that pupae and prepupal larvae are apt to be killed by sudden frosts, while eggs, young, larvae, mature larvae, and adult beetles may pass th

may pass thru extremely cold weather intact.

Effect of Heat.

Log 38:

Aug. 27, 1915:- Under side of log with fair number of exit holes. Apparently no emergence on top of log where exposed to hottest sun.

This condition, of the failure of the brood on the top side of an infested log, or in one which has been cut after being infested, has been noticed many times. The only apparent explanation is that the bark becomes so heated in the summer sun that the beetles either fail to develop or are killed.

Cage B:

June 12:- 150 D. brevicomis taken from cage placed on a pine board in the sun. All died within about 20 seconds. The temperature was about 95, but the board was considerably hotter.

Even on cooler days many of thebeetles used in the filght experiment died when exposed to the direct rays of the sun.

Heat then may also kill a great many beetles in the summer.

Disease.

Tree 54:

May 10:- A freeze occurred which killed larvae and pupae.
May 19:- Larvae noted.
June 3:- Retarded larvae flat and white.
" 9:- " " " " "
" 17:- " " " " "
" 24:- Last " " " " , Last adults, and last emerging.
July 3:- Although most of the brood has developed and emerged, there are still quantities of full grown larvae, possibly a case of retartation.
July 15:- Some retarded larvae, pupae and 1 adult found.
July 22:- Flat and white larvae found as since June 24th, but on close examination with a hand lens they were found to be lifeless. One was noted with cobweb-like hairs around it.
Aug. 21:- A slab of bark containing these larvae, and larvae in alcohol, are sent to Washington D.C. to determine if a disease was present.
Sept. 1:- Dr. Speare reports, "I have carefully examined the larvae in alcohol and those in the bark and have been unable to determine the presence of any parasitic fungus.

While it is impossible for me to render a determination regarding the presence of other possible parasitic organisms such as bacteria, protozoans etc., I do feel that the above larvae died

from some cause not due to parasitic organisms, for characteristic symptons are generally absent."
Sept. 23:- Found i dead "retarded" larva. Most of these had withered up or had been parasitized. Some papery skins were found in the pupal cells, indicating parasitism.

Tree 34:

July 3;- Found sick pupae and sick larvae in bark.
" 8:- " " larvae in bark.
" 29:- " " " " " undoubtedly dead and in similiar condition to those found in tree 54.

These records show that some of the larvae and pupae of D. brevicomis are killed by something in the nature of a disease.

Parasites and Predators.

Parasites of D. brevicomis are not abundant and are rarely found.

Three, probably, parasites have bee found in the course of this study. They were all found ovipositing in the bark of an infested tree.

Tree 311:

Aug. 31, 1916:- Noted several parasites of three different species ovipositing in the bark of this tree which was heavily infested with D. brevicomis, in the larval, pupal and adult stages.
They were ~~ind~~- identified by Mr. S.A. Rohwer as-~~Eurytoma sp~~

Eurytoma sp.
This small black chalcid ~~was ovipositing~~ ovipositing int thru the bark, inserting its ovipositor for nearly a quarter of an inch in the same manner as the seed chalcids (Megastigmus spermotrophus and M. pinus) oviposited in the fir cones.

Cecidostiba burkei Cwfd.
This long bronze chalcid was observed ovipositing into the creavices of the bark.
It was also reared rather abundantly from the infested bark in Cage B.

Roptrocerus sp. A.
This small chalcid was observed running over the bark, backing into the ventilating holes and laying its eggs inside of them.

Predators.

The predators are more abundant, at least in numbers, than the parosites.

The following have been observed by the writer and identified by Mr. Fisher.

SUMMARY

The following is a summary of the important facts brought out by this intensive study of the infestation on the 3200 acres of the Lanb's Mine Unit:-

Page (1)

1 D. brevicomis will attack and breed in Sugar Pine if forced to do so.

2 Parent adults with normal food live for 244 days. Page (2)

3 Beetles without food only live 15 days. (Page 2)

4 Females, both in emerging and attacking, outnumber the males 54 to 46. Polygamy is found to occur. (Page 3)

5 Females are capable of laying eggs 3 days after emergence. (Page 4)

(Page 4)

6 Copulation occurs in the newly constructed galleries, or brood chambers.

7 Attack is not concerted bun continuous, commencing at the top of the tree as a rule and working down the tree. (Page 5)

8 D. brevicomis beetles make a distinct noise when attacking trees. (Pa 6)

9 Females make the attack, and are followed by the males. (Page 7)

10 The gallery is constructed at the rate of .65 inches per day. (Page 8)

11 Emergence is continuous for a considerable period of time, and not concerted. (Page 16)

12 Straggling emergence may last for 99 days. (Page 18)

13 Overwintered Parent adults emerge in the spring, but their attack is weak and only on parts of previously infested trees. (Page 18)

14 Parent adults also emerge from trees which they have attacked during the active season, and probably make a second attack. (Page 20)

15 Flight of the beetles lasts for approximately 26 days. (Page 21)

16 Parent adults, eggs, small to full grown larvae, and new adults are found to overwinter. (Page 22)

17 Only about 5% of the overwintering generation, overwinter in the adult stage; while about 75% overwinter as full grown larvae. (Page 22)

18 The overwintering period of inactivity is approximately 80 days. (Page 23)

19 The average event periods are as follows:- (Table X-k and X-l--Page 39)

Attack to eggs--11 days.

Egg to hatching of larvae--24 days--overwintering 127 days.

Hatching of larvae to it's pupation--42 days--overwintering--164 days.

Pupae to forming of adult--21 days.

Adult to it's emergence--13 days.

20 The average duration periods are as follows:- (Page 39)

Duration of attack--30 days.

Eggs, first to last--31 days.

Larvae, hatching; first to last--31 days.

Pupating, first to last--35 days.

Adults, first to last--31 days.

Emerging, first to last--40 days.

21 The average brood period, from first attack to last emerging, for the 1st seasonal generation is 109 days; for the second generation 242 days. (Page 39)

The minimun recorded brood period is 54 days.

The amximum recorded brood period is 348 days.

22 There are three distinct periods of activity each year. There is in general; one annual generation with a partial second and a partial third generation. (Page 40)

At Ashland Oregon, there is a maximum of 2 annual generations and a partial 3rd; a minimun of 1 annual generation and an average of 1 annual generation and a partial 2nd.

23 D. brevicomis is "adaptive", modifying it's activities, number of generation etc. to the conditions under which it finds itself. (Page 43)

24 The seasonal history of D. brevicomis at Ashland Oregon, may be briefly summerized as follows:- (Page 43)

The broods pass the winter in all staged from parent adults, egg, larvae, to new adults and posibly pupae.

Beginning with the first warm weather in February, activity of all stages commences, and emergence soon gegins reaching its maximum during May and June, and continuing until the first of September.

Attack, of the first seasonal generation begins about the first of March, and continues thru the summer until the first of August, when the attact of the second generation begins; from beetles emerging from the overwintering stages and from the first e generation. The maximum attack of the second generation occurs during September and October. A few beetles of this generation

d develop and emerge before cold weather and produce a partial third generation , but the majority of the brood passes the winter in all stages; principally in the larval stage and this constituting the overwintering generation. Thus there is one complete annual generation and two partial ones.

25 The possibilities of overlapping generations are immumerable hence no comparison of the summer generations can be made with the overwintering generations to determine whether the beetles are increasing or decreasing. (Page 44)

It follows that in order to determine increase or decrease, either successive overwintering generations should be compared; or the total yearly loss from year to year of all generations should be compared.

26

26 Average shows:- (Page 51)

Attacks per sq.ft.---6.8

Parent adults per sq.ft.---17.66

Females " " --- 9.85

Males " " --- 7.75

Inches of galler per sq.ft. ---187.8

Eggs " " --- 636

Vent holes " " --- 17.7

Emergence " " --- 80

Parent adults per attack --- 2.59

Vent holes " " --- 2.61

Eggs per female --- 64.6

Females per male --- 1.27

Eggs per inch of gallery --- 3.39

Inches of gallery constructed per day --- .65 inches.

Eggs laid per day --- 2.20

27 About 12% of emergence of the overwintering generation make the attack of the 1st generation. (Page 52)

28 Climate is one of the natural control agencies. (Page 53)

Cold kills pupae and prepupal larvae.

Heat, in summer, kills adults on the outside and some of the brood on the inside of logs.

29 Three species of parasites have been found ovipositing in infested trees. (Page 55)

30 Predators, especially, Clerid beetles, render good assistance in natural control of the beetles. (Page 55)

31 Woodpeckers are the most effective natural control agency. (Page 56)

They destroy 75% of the larvae in the bark which they work on.

To fit the conditions at Ashland, Oregon the account of the Seasonal History of D. brevicomis as given, by Dr. A. D. Hopkins, in Bulletin 83, may be revised as follows:- (Revisions are underlined.)

Overwintering Stages.

The broods pass the winter in the outer bark of trees attacked the preceeding, late summer and fall, as parent adults, young adults in the papal cases, all stages of larvae, eggs and possibley pupae.

Activity of Overwintered Broods.

The overwintered parent adults extend their galleries of emerge and attack the infested portions of weakened trees and deposit eggs during March, April and May from which broods develop and emerge by the last of July to the middle of August. The broods of young adults in the pupal cells begin to emerge about the first of March and continue to come out until the middle of April. The broods of overwintered larvae begin to transform to pupae about the first of March, and to adults towards the last of March , and the latter begin to emerge from the trees about the first to last of April, with the greatest emergence about the first of June so that all of them are out by the last of July. The overwintered eggs transform to larvae about the middle of February to the last of April, to pupae from the first of May to the last of June; to adults from the last of May to the middle of July, and emerge from the trees from the middle of June to the last of August, so that the last of the overwintered brood are out of the trees by the first of September.

First Generation.

Adults developing from the overwintered broods begin to attack the trees, excavate galleries and deposit eggs about the first of March and continue their activities ~~and continue their activities~~ until the first of August. The principal period of attack is during June. The larvae

begin to hatch in from 7 to 40 days after the eggs are deposited, and may be found in the bark of the trees from the first of May until September, but the principal development is during June and July. They begin to transform to pupae about the first of July, and continue transforming until the first of October, the principal period of tranformation being from the middle of July to the last of August. The pupae tranform to adults about the middle of July, and continue transforming until the first of October, the principal period of transformation is about the first of August.

The adults begin to emerge towards the last of July, and continue to come out until November, of later, but the principal period of flight appears to be from the middle of August to the last of September. While the majority of the broods of this generation emerge before cold weather, in very rare cases a few of the new adults overwinter in the bark of the trees.

Second Generation.

The records of observation indicate that the earlier emerging adults of the first seasonal generation and the later emerging adults of the overwintering generation, begin to deposit eggs about the last of July, and that the principal period of attack is from the middle of August to the last of September. The larvae begin to appear towards the last of August and continue to hatch until November. A few of the larvae of this generation transform to pupae, about the first of October, to adults a few days later and emerge towards the middle or last of October. The remainder of the broods pass the winter in all stages of larvae, eggs, parent adults, and a few of the new adults.

Third Generation.

The emerging adults of the second generation attack about the first of November. The broods overwinter in the egg stage.

Number of Generations.

Thus, there is one complete generation annually, and two partial ones.

Control.

At Ashland, Oregon trees should be located between October and March, and the work of treating the infested trees completed, if possible, before the first of May, or in other words before the period of maximum emergence.

Summer operations are not to be recommended, except in special cases, since the first generation is only a partial one and only represents about 12% of the overwintering broods.

Respectfully submitted,

F. P. Keen.

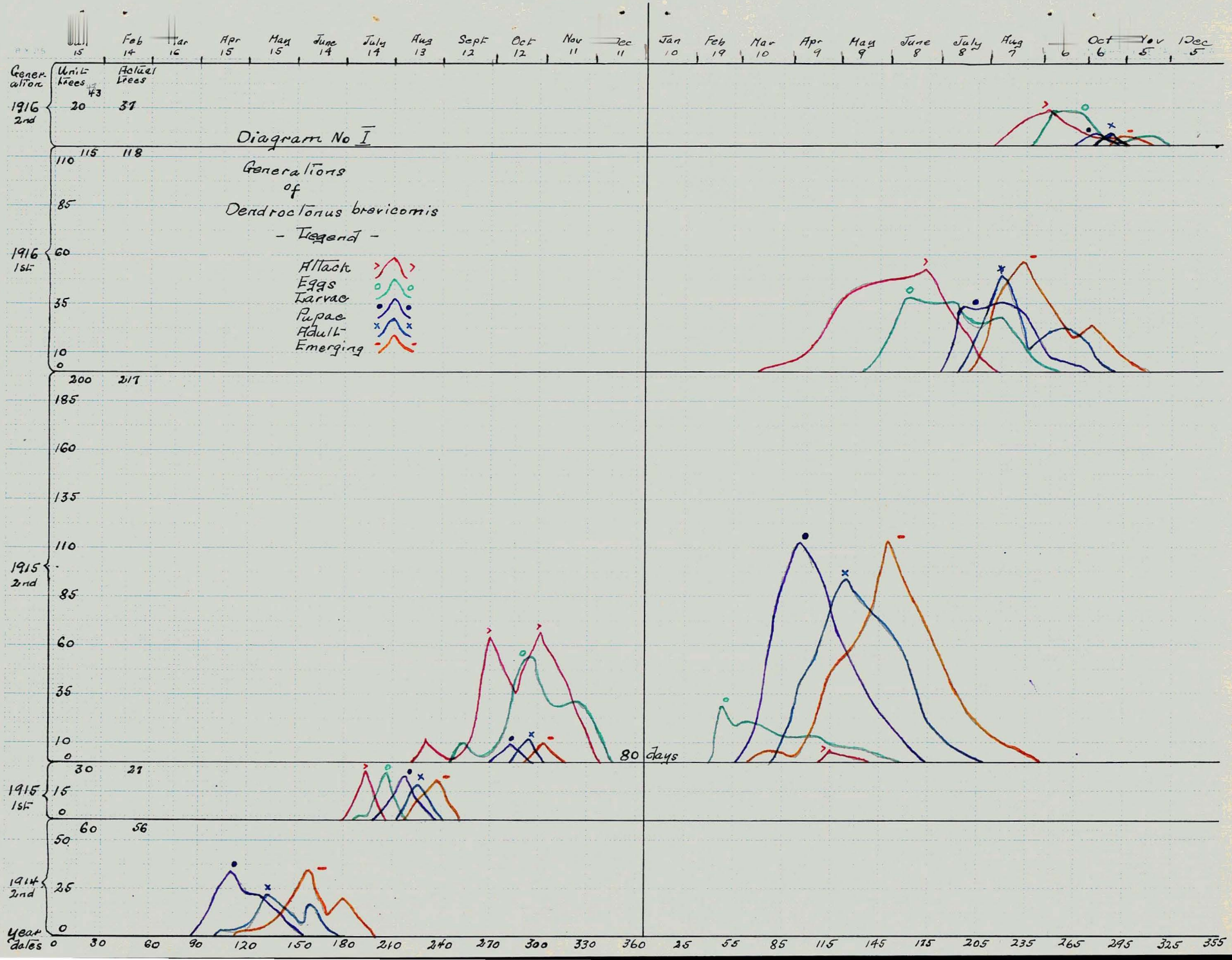
Pacific Slope Station. Scientific Assistant.

Ashland Oregon.

Feb. 10, 1917.

ASSOCIATED STUDENTS' STORE

ASSOCIATED STUDENTS' STORE



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Jan Feb Mar April May June July Aug Sept Oct Nov
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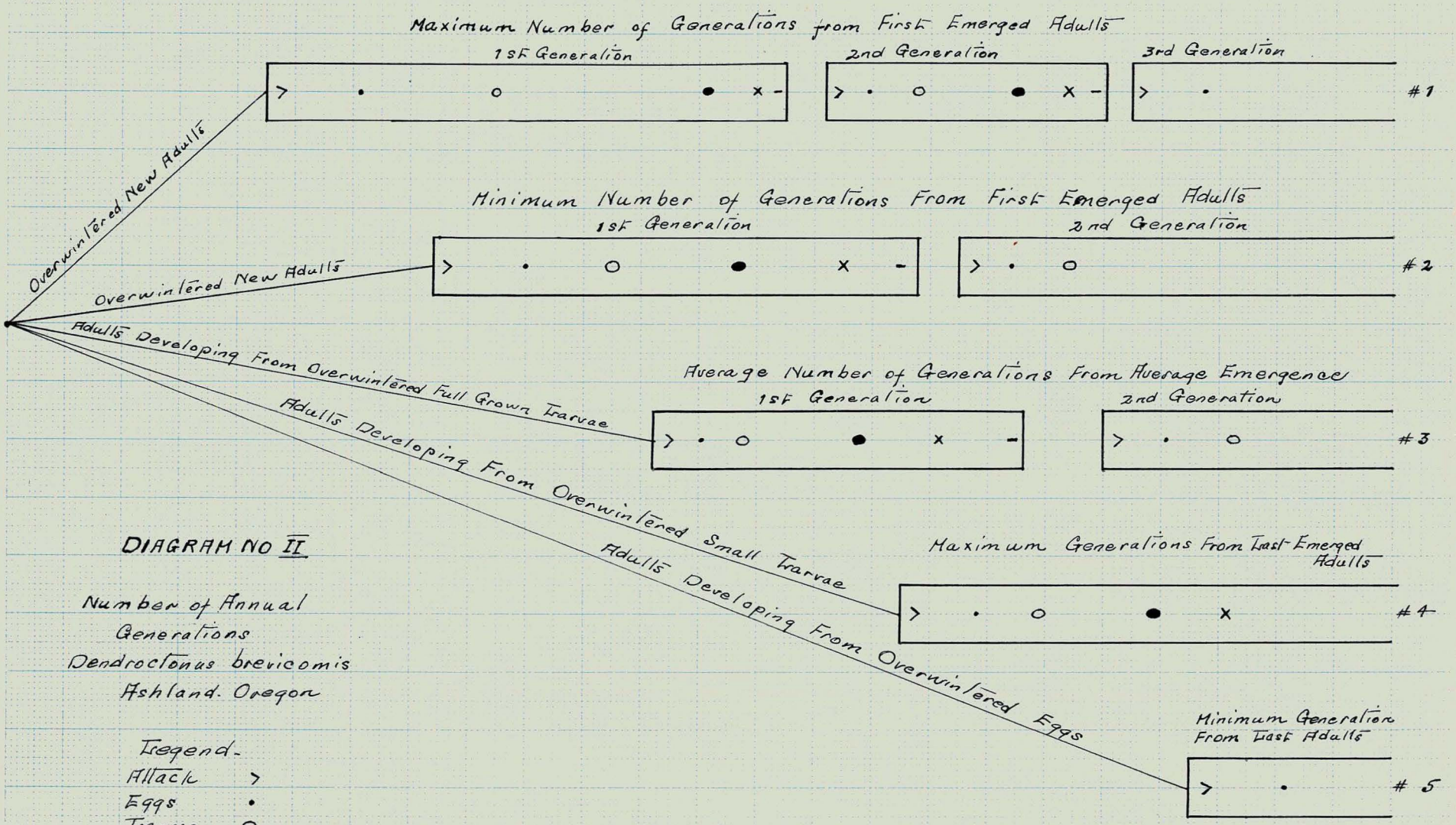

DIAGRAM NO II

Number of Annual Generations
Dendroctonus brevicomis
Ashland. Oregon

Legend-

Attack	>
Eggs	•
Larvae	o
Pupae	●
Adults	x
Emerging	-

ASSOCIATED STUDENTS' STORE.

Diagram #8

Total Number of Beetles Emerging and Attacking for Each Generation

- Legend -

Emergence ——

Attack ——

Beetles

3,400,000
3,200,000
3,000,000
2,800,000
2,600,000
2,400,000
2,200,000
2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0

1915: Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec

1916: Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec

1914-2nd — 56 actual trees — 38,100 B.F. Volume

1915-1

1915-1 — 27 trees — 21,580 B.F.

1915-2nd

1915-2nd

1915-2nd — 217 actual trees — 119,500 B.F. Volume.

1916-1

1916-1st — 101 actual trees — 67,600 B.F. Volume.

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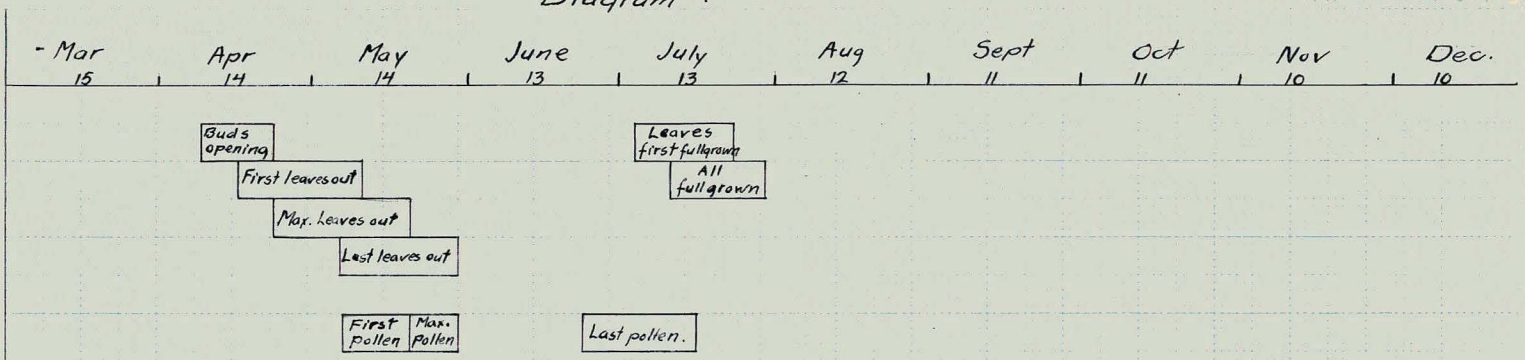
Diagram #1



Dendroctonus brevicomis Periods of Attack

1st Generation			2nd Generation		
First Attack	Maximum Attack	Last Attack	First Attack	Maximum Attack	Last Attack

Dendroctonus monticolae Periods of Attack

Partial Generation			Main Generation		
First Attack	Maximum Attack	Last Attack	First Attack	Maximum Attack	Last Attack

Ips confusus Periods of Attack

1st Generation.			2nd Generation.		
First Attack	Maximum Attack	Last Attack	First Attack	Maximum Attack	Last Attack